MEMORANDUM

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HSM-11005
(HSM-12005 supercedes this HSM)

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SUBJECT: PRIMARY REVIEW OF TURF REENTRY EXPOSURE MONITORING AND RESIDUE DISSIPATION STUDY WITH OXADIAZON

This memorandum (memo) reviews data from a study monitoring residue dissipation and reentry exposure on turf treated with a liquid oxadiazon product (Rosenheck and Sanchez, 1995). This study was submitted by a registrant to the California Department of Pesticide Regulation (DPR) to support registration of carbaryl products on turf. Rosenheck and Sanchez (1995) is a well conducted study that provides useful data for both occupational and residential reentry scenarios following spray turf applications, and is particularly useful for estimating exposure when reentry occurs on the same day as application. Reentry exposures were monitored on two treated plots, one of which was irrigated as soon as the spray was dried. This memo provides residential and occupational exposure estimates for reentry onto both non-irrigated and irrigated turf.

Chemical-specific residue dissipation rates can be useful for estimating long-term exposures, when individuals are assumed on average to enter several days post-application. Dissipation of transferable turf residues measured by Rosenheck and Sanchez (1995) using the California roller method suggest a half-life of about 4 days for an oxadiazon liquid product on non-irrigated turf. Rain occurred on the last 3 days of the 7-day interval when turf residues were monitored, but did not alter the half-life, which was 4 days both when the last 3 days were included and excluded from the regression. For the irrigated plot, including the entire 7 days yielded a half-life of 8 days; excluding the last 3 days when rain occurred resulted in a half-life of 6 days. Dissipation is considered to be chemical-specific, applying in this case only to oxadiazon, and might be different in California, particularly during the state's typical hot, dry summers.

Study Design

The study site was a commercial turf farm near Princeton, NC. Two plots were marked for treatment on 2-year-old Bermuda grass (variety "419"), which was 2 – 3 inches tall and dormant (the field portion of the study was conducted on January 23, 1994, and the grass is described as "dry and brittle"). Each plot was 40 x 50 ft (2,000 ft^2), and the plots were separated by 100 ft. In addition to the treated plots, one plot measuring 50 x 20 ft (1,000 ft^2), located 163 ft upwind of the treated plots, was used as a control. The two treated plots received a broadcast application of Ronstar® 50WP, applied with a tractor-mounted boom sprayer, at an application rate of 3.0 lbs active ingredient (AI) per acre. One of the treated plots was irrigated following the application with approximately 0.1 inches of water (page 23 of the study report).

Ten study participants (four male and six female volunteers) entered the non-irrigated study plot after the spray dried. The plot had been marked with 10 x 10-ft subplots, one for each volunteer. They performed a 16-minute Jazzercise® routine on the turf, from 11:43 AM to 11:59 AM. Rosenheck and Sanchez (1995) characterized the routine as follows (page 24 of the study report): "The routines…involved such moves as sit-ups, leg lifts, and stretching which provided substantial continuously-moving contact with the treated turf in an attempt to maximize the dislodgeability of oxadiazon from the turf to the body dosimeters." The same ten volunteers performed a 17-minute Jazzercise® routine on the irrigated plot that afternoon, after changing clothes and showering.

Dermal exposure was monitored with outer whole-body dosimeters, cotton gloves, hand washes, and face/neck wipes. Outer whole-body dosimeters consisted of prewashed 100%-cotton long underwear, worn outside the volunteers' clothing (nothing was worn over the dosimeters, which represented unprotected skin). At the end of the monitoring intervals, the dosimeters were removed by test participants, assisted by study personnel wearing latex gloves. The outer whole-body dosimeters were cut into three portions: arms, upper body and lower body. Solvent-cleaned scissors were used to section dosimeters. Dosimeter sections were placed in labeled metallic Kapak® bags, which were then heat-sealed and placed in ice chests with dry ice.

Hand exposure was monitored with both cotton gloves and hand washes. Each volunteer wore thin Costar-brand, 100%-cotton gloves. At the end of the monitoring intervals, gloves were removed and combined (i.e., each glove sample consisted of a pair), placed in Kapak® bags, heat-sealed and placed in ice chests with dry ice. To capture oxadiazon that might have passed through the glove or its wrist opening, hand washes were conducted after glove removal. Hand washes consisted of the volunteer immersing their hands and washing them for about 45 seconds in 300 ml of a 0.01% aqueous Aerosol® OT-75 (sodium dioctyl sulfosuccinate) detergent solution in a 1-gallon plastic bag. The hand wash solution was then poured into a 16-ounce glass jar, which was capped with a Teflon®-lined lid and placed into a cooler of dry ice.

Face and neck exposure was monitored by wiping the skin with two gauze squares wetted with 4 ml of 0.01% Aerosol® OT-75 detergent solution. The two wipes were placed in a glass jar, which was capped with a Teflon®-lined lid and placed into a cooler of dry ice.

Foot exposure was monitored with prewashed 100% cotton socks. At the end of the monitoring interval, socks were removed by study personnel wearing latex gloves. Socks were placed in labeled metallic Kapak® bags, which were then heat-sealed and placed in ice chests with dry ice. Test participants wore plastic disposable booties over the socks before and after the monitoring interval.

In addition to exposure monitoring, environmental sampling was conducted of turf in treated and control plots, and of air above the treated plots. Residues potentially available for inhalation exposure were monitored using personal air samplers mounted above both the irrigated and non-irrigated treated plots. Each sampler consisted of a 37-mm diameter glass fiber filter, with 1.0-µm pore size, which was placed into a plastic cassette along with a cellulose support pad and attached to a pump. Sampler pumps were calibrated at a flow rate of 1.5 liters/minute. Two samplers were used on each treated plot, one which sampled at 6 inches above the turf to represent an infant's breathing zone, and one which sampled 36 inches above the turf to represent the breathing zone of an older child or adult sitting on the turf. At the end of the monitoring intervals, cassettes were removed from air samplers, and put into Kapak® bags, which were then heat-sealed and placed in ice chests with dry ice.

Dislodgeable foliar residues (DFR) were sampled from turf clippings collected from 40 x 40 cm squares placed on the turf. Triplicate samples were collected daily from each plot (untreated, treated without irrigation, and treated with irrigation). Acetone-cleansed garden clippers were used to cut grass down to the thatch level. Clippings were put into re-closeable plastic bags and placed into coolers with substitute ice. Samples were weighed on a balance and a 9.5- to 10-g aliquot from each was dislodged within 3 hours (0 hour samples were dislodged 6 hours post-collection) in a 12-ounce jar with 150 ml of a 0.01% aqueous Aerosol® OT-75 detergent solution. Jars were capped with Teflon®-lined lids and shaken for 20 minutes on a reciprocal shaker operating at 200 cycles/minute. The solution was decanted into a 16-ounce glass jar and samples were shaken for another 20 minutes with a second 150-ml aliquot of detergent solution. The second aliquot was combined with the first in the glass jar, which was then closed with a Teflon®-lined lid and placed into a cooler of dry ice. A Seescan Imaging Analyzer was used on three 1- to 2-g turf clipping samples collected concurrently with DFR samples to estimate leaf area per gram sample.

In addition to DFR, transferable turf residues (TTR) were monitored with cloth dosimeters using the California roller method published by Ross *et al.* (1991). Dosimeters consisted of 31 x 59 cm (1,829 cm^2) sections of white 100% cotton t-shirt material, three layers thick. Three dosimeter sets were placed in each plot; each was covered with a clean towel before a 15-kg roller was rolled over it back and forth ten times. Samples were then handled as follows (page 29 of the study report): "the towels were removed, and the dosimeters were lifted off the turf, gently shaken to remove as much foliage as possible, folded (treated surface facing treated surface), and placed into separate prelabeled metallic Kapak® bags." The bags were placed in ice chests with substitute ice for transport to the "temporary laboratory," where they were heat-sealed and put into coolers with dry ice. It's not clear from the study report whether the "temporary laboratory" where DFR samples were dislodged and TTR samples were heat sealed was the same as the "sample handling area" where outer whole-body dosimeters were removed, sectioned and placed in bags that were then heat-sealed.

Although exposure monitoring was conducted only on the day of application (Day 0), DFR and TTR samples were also conducted daily for seven days post-application. The time of day when sampling occurred after Day 0 was not stated; the samples are identified only as 1 DAA (day after application), etc.

Analytical Methods

Dosimeter sections were placed into 1-gallon glass jars with Teflon®-lined lids and extracted first with 50% acetone then with hexane. Cloth dosimeters used for TTR, gloves, and socks were extracted in the same sequence, but in smaller glass jars. Hand wash samples were extracted for 30 seconds in a separatory funnel, using 50% w/v sodium chloride in acetonitrile and hexane as aqueous and organic phases. The organic (hexane) phase was retained for analysis, and the aqueous phase was extracted a second time with hexane, which was then combined with the first organic phase. After evaporating the combined organic phase until it was nearly dry, its final volume was adjusted to 1 ml with hexane for analysis.

Face wipes were extracted within their sample jars by adding 5 ml of Aerosol® OT-75 detergent solution and 50 ml of hexane and shaking for 5 minutes. The hexane extract was poured into a 250-ml flat-bottom flask, and a second 50-ml aliquot of hexane was added to the sample jar for additional extraction. Extracts were combined and evaporated to dryness. The final sample volume was adjusted to 1 ml with hexane for analysis.

Glass fiber filters and cellulose backings were extracted by shaking with 50 ml of hexane for 5 minutes. The hexane extract was poured into a 250-ml flat-bottom flask, and a second 50-ml aliquot of hexane was added to the sample jar for additional extraction. Extracts were combined and evaporated to dryness. The final sample volume was adjusted to 1 ml with hexane for analysis.

All samples were analyzed using gas chromatography with a nitrogen phosphorus detector. Helium was used as a carrier gas. The limit of quantitation (LOQ) for each matrix was 5.00 µg oxadiazon/section for outer whole-body dosimeter sections; 5.00 µg oxadiazon/pair of socks; 5.00 µg oxadiazon/sample for TTR cloth dosimeters; 0.500 µg oxadiazon/pair of gloves; 0.100 µg oxadiazon/300 ml hand wash and DFR dislodging solutions; 0.100 µg oxadiazon/2 swabs for face/neck wipe samples; and 0.100 µg oxadiazon/filter for glass fiber filter samples.

Quality Assurance

<u>Methods</u>

Quality assurance consisted of field controls, field spikes, laboratory controls, and laboratory spikes. Each set of samples was analyzed along with a set of calibration standards, a solvent blank, a laboratory control matrix, and newly fortified laboratory spikes.

Field controls consisting of duplicate samples of each matrix were taken into the field and placed about 200 ft upwind of the control plot for the entire monitoring duration, from 11:20 AM to 5:15 PM (including reentry into non-irrigated plot, followed by reentry into irrigated plot). Control hand wash and face/neck wipe samples were placed in glass jars and put on dry ice immediately. Control dosimeter sections were set out until exposure monitoring was complete, when they were placed in labeled metallic Kapak® bags, which were heat-sealed and placed in ice chests with dry ice.

Field spikes consisting of triplicate samples of each matrix were spiked at three levels on the monitoring day using the formulated product, Ronstar® 50WP, dissolved in acetone (glass fiber filters were spiked with formulated product dissolved in toluene). Outer whole-body dosimeter, sock, and TTR cloth dosimeter samples were fortified at 20.0 µg, 200 µg, and 2,000 µg oxadiazon. Gloves were fortified at 2.00 µg, 20.0 µg, and 200 µg oxadiazon. Hand wash solution, DFR dislodging solution, and face/neck wipe samples were fortified at 0.500 µg, 5.00 µg, and 50.0 µg oxadiazon.

Hand wash (300 ml of 0.01% Aerosol® OT-75 solution) and face/neck wipe (2 wipes in 8 ml of 0.01% Aerosol® OT-75 solution) samples were placed in glass jars immediately after spiking. Jars were capped with Teflon®-lined lids after about 10 minutes environmental exposure and put into coolers. Field spikes of dislodging solution were prepared by first dislodging samples of untreated grass clippings; after shaking with dislodging solution, the clippings were discarded and the solution was spiked.

Weathering of other types of field spike samples was done as appropriate. Spiked outer whole-body dosimeter sections, socks, and gloves were weathered for 20 minutes; then they were put into Kapak® bags, which were heat-sealed and placed in ice chests with dry ice. TTR cloth dosimeters were weathered for 10 minutes after spiking, then put into Kapak® bags, which were heat-sealed and placed in ice chests with dry ice. Spiked plastic cassettes containing glass fiber filters and cellulose backing were connected to sampler pumps. After air was drawn through the cassettes for about an hour (longer than the 16- or 17-minute monitoring interval, thus providing conservative estimates of any analyte loss that might occur), they were disconnected from the pumps and put into Kapak® bags, which were then heat-sealed and placed in ice chests with dry ice.

Exposure matrix field spikes were done on the application day (Day 0), which was the only day exposure monitoring was conducted. To obtain residue dissipation curves, TTR and DFR were monitored daily from the application day through Day 7 post-application, and those field spikes were done on Day 0, Day 3, and Day 5.

Results

Quality assurance was acceptable. No quantifiable oxadiazon was recovered from 44 of 46 laboratory controls. Of the two laboratory controls with quantifiable oxadiazon, one outer whole-body dosimeter control was believed to have come in contact with a container from the test site (no result was reported for this control), and one TTR cloth control reported a result of 8.46 µg oxadiazon without explanation (the LOQ was 5.00 µg/sample). No quantifiable oxadiazon was recovered from any field control. For each matrix, mean laboratory spike recoveries ranged from 84.2% to 114%, and mean field spike recoveries were 64.7% – 109%.

Table 1 summarizes overall field spike recoveries for exposure matrices. Rosenheck and Sanchez (1995) adjusted samples for matrix mean recoveries across all spike levels: 99.2% for outer whole-body dosimeters, 99.6% for socks, 95.8% for gloves, 64.7% for face/neck wipes, 88.2% for hand wash, and 91.1% for glass fiber filters. Rosenheck and Sanchez (1995) calculated lower means than indicated by Table 1 for outer whole-body dosimeters, socks, gloves, and glass fiber filters because they substituted 100% for any individual recovery result exceeding 100%.

Table 1. Oxadiazon Field Spike Recoveries in Exposure Matrices and Air Samplers [a]

Matrix	Spike Levels [b] (µg)	Percent Recovery (Mean ± Standard Deviation) [c]		
		Low	Mid	High
Dosimeter [d]	20, 200, 2,000	**110** ± 9.7	**103** ± 6.3	**104** ± 8.8
Socks	20, 200, 2,000	**118** ± 7.0	**113** ± 3.8	**109** ± 11.2
Gloves	2.0, 20, 200	**98.2** ± 3.1	**102** ± 10.0	**98.5** ± 18.0
Face/Neck Wipes	0.5, 5.0, 50	66.4 ± 9.4	75.3 ± 9.7	52.4 ± 19.3
Hand Wash	0.5, 5.0, 50	88.0 ± 12.6	84.9 ± 7.6	**93.2** ± 6.5 [e]
Glass Fiber Filters	0.5, 5.0, 50	**113** ± 20.1	89.3 ± 8.0	84.1 ± 9.9

[a] Data from Rosenheck and Sanchez (1995).
[b] The three levels listed correspond to low, mid, and high level spikes.
[c] Each mean and standard deviation is of 3 replicates, unless otherwise indicated. Means at or above 90% are shown in bold; the practice of the California Department of Pesticide Regulation is to correct only for recoveries less than 90%, and DPR did not correct samples in the range of spikes ≥ 90% for spike recoveries.
[d] Outer whole-body dosimeter sections.
[e] Mean and standard deviation of two samples; one was broken before analysis.

In this memo, results were corrected according to DPR practice, which is in general agreement with U.S. EPA policy: samples were corrected for field fortification recoveries below 90% (U.S. EPA, 1992; U.S. EPA, 1998a). In Table 1, mean spike recoveries not requiring correction under this criterion are shown in bold. With the exception of hand wash and face/neck wipes, sample results reported in this memo were not corrected for mean field spike recoveries (glass fiber filter samples were either below the LOQ or in the range of the low level spike and did not require correction).

Table 2 summarizes overall field spike recoveries for DFR dislodging solution (used to dislodge residues from grass clippings) and TTR cloth dosimeter samples. With the exception of low and mid level DFR dislodging solution spikes on Day 0, all mean DFR and TTR spike recoveries exceeded 90%; there were difficulties with low and mid level DFR spikes on Day 0, as summarized in Table 2. However, all Day 0 DFR samples were in the range of the high level spike, which had acceptable recoveries and did not require correction under DPR practices. In this memo, TTR and DFR results were not corrected for spike recoveries. Rosenheck and Sanchez (1995) corrected DFR results using the mean spike recovery of 95.3%, and they corrected TTR samples for the mean spike recovery of 95.7%.

Table 2. Dislodgeable Matrix Oxadiazon Field Spike Recoveries [a]

Matrix [b]	Spike Levels [c] (µg)	Percent Recovery (Mean ± Standard Deviation) [d] Low	Mid	High
Day 0				
TTR Cloth	5.0, 50.0, 500	**102** ± 10.4	**96.9** ± 3.6	**115** ± 78.2
DFR Solution	0.5, 5.0, 50.0	74.7 ± 13.0 [e]	71.7 ± 24.3 [e]	**90.9** ± 5.1
Day 3				
TTR Cloth	20, 200, 2,000	**105** ± 9.4	**99.5** ± 9.1	**101** ± 9.6
DFR Solution	0.5, 5.0, 50.0	**113** ± 5.6	**110** ± 11.4	**103** ± 2.4
Day 5				
TTR Cloth	20, 200, 2,000	**115** ± 4.9	**104** ± 7.8	**96.2** ± 9.4
DFR Solution	0.5, 5.0, 50.0	**126** ± 28.8	**95.2** ± 4.5	**98.5** ± 7.6

[a] Data from Rosenheck and Sanchez (1995).
[b] TTR = transferable turf residue, California roller method of Ross *et al.* (1991). DFR = dislodgeable foliar residue, solution used to dislodge residues from grass clippings.
[c] The three levels listed correspond to low, mid, and high level spikes.
[d] Each mean and standard deviation is of 3 replicates. Means at or above 90% are shown in bold; the practice of the California Department of Pesticide Regulation is to correct only for recoveries less than 90%, and DPR did not correct samples in the range of spikes ≥ 90% for spike recoveries.
[e] Mean and standard deviation include re-analyzed samples; initial analysis of two low level and one mid level spike yielded results of 232% – 1914% recoveries, but re-analysis yielded results of 44% – 75% recoveries. Omitting these results would give a single sample having 87.6% recovery for the low spike, and two samples averaging 85.5% recovery for the mid level spike. No samples were in the range of these spikes on Day 0.

Results of Exposure Monitoring

Non-Irrigated Oxadiazon Plot

Table 3 summarizes exposure monitoring results for participants on Plot 1, the non-irrigated treated plot. Individual results are reported in Table 3, as well as the sum of all residues recovered for each participant. For each exposure matrix, the mean, standard deviation, and coefficient of variation are given. Body weights are included to allow calculation of exposure estimates normalized to body weight. The monitoring interval was 16 minutes.

Oxadiazon was detected in all exposure monitoring matrices, for all ten replicates. The exposure matrix coefficients of variation (CVs) ranged from 18.6% for socks to 63.3% for hand washes. Results in which the standard deviations are all smaller than the means (i.e., CVs all less than 100%) suggest relatively small variation for an exposure monitoring study, where exposure ranges commonly exceed an order of magnitude (Kromhout *et al*., 1993). One factor possibly contributing to this small variation is the choreographed nature of monitored activities, in which subjects all made fairly synchronized movements.

Table 3. Oxadiazon Residues on Dermal Exposure Monitoring Matrices for Reentry on Non-Irrigated Turfgrass [a]

# [b]	Body Weight (kg)	Gloves (µg)	Hand Wash (µg)	Face/ Neck (µg)	Socks [c] (µg)	Arms [c] (µg)	Upper Body [c] (µg)	Lower Body [c] (µg)	Total Dermal [d] (µg/person)
1	63.6	658	66.6	2.23	3,120	561	1,610	1,750	7,770
2	58.6	1,580	28.3	2.80	3,770	694	1,170	2,420	9,670
3	72.7	1,220	19.4	1.73	3,150	531	1,140	1,860	7,920
4	59.5	1,570	72.8	4.41	4,550	691	1,320	1,570	9,780
5	84.1	2,050	129	3.07	4,160	914	2,240	2,030	11,500
6	54.5	1,500	30.6	3.34	3,990	698	1,130	1,440	8,790
7	90.0	1,800	57.5	2.42	2,890	530	2,500	1,640	9,420
8	57.1	997	21.5	1.39	3,100	553	1,590	1,980	8,240
9	86.4	1,470	107	1.64	4,080	459	1,740	1,240	9,100
10	65.9	1,710	50.2	2.38	5,010	632	229	1,240	8,870
Mean	69.4	1,460	58.3	2.54	3,780	626	1,470	1,720	9,110
SD	13.0	404	36.9	0.907	705	130	636	372	1,090
CV	18.8	27.8	63.3	35.7	18.6	20.8	43.3	21.6	12.0
Mean residue if wearing single layer of clothing [e]					378	62.6	147	172	2,280

[a] Data from Rosenheck and Sanchez (1995). Results corrected for field spike recoveries according to California Department of Pesticide Regulation practice (see Table 1), and rounded to three significant figures.

[b] Replicate number. Ten individuals were monitored during a 16-minute interval involving choreographed activities on turf sprayed with a solution of Ronstar® 50WP. SD: standard deviation. CV: coefficient of variation.

[c] Replicates wore socks without shoes, and outer whole-body dosimeters that were then sectioned into three parts: arms, upper body, and lower body.

[d] Total residues recovered from cotton gloves, hand wash, face/neck wipes, socks, and outer whole-body dosimeter.

[e] Estimates assume 90% clothing protection factor for individuals wearing shoes, long-sleeved shirt, and long pants (Thongsinthusak *et al.*, 1991). Used in calculating estimates of occupational exposure.

The highest proportion of residues was recovered from socks, and the lowest from face/neck wipes. On average, 41% of total dermal oxadiazon measured (mean: 9,110 µg/person) was recovered from socks (mean: 3,780 µg/person), while just 0.03% was recovered from face/neck wipes (mean: 2.54 µg/person).

As no clothing was worn over the outer whole-body dosimeters, residues recovered from dosimeter sections represent exposure of someone wearing minimal clothing, such as only shorts. Similarly, because shoes were not worn over socks during exposure monitoring, socks represent exposure of bare feet. Foot exposure would be expected to be lower for individuals wearing shoes, and exposure would be expected to be lower for parts of the body covered by clothing. In order to predict exposure to those individuals wearing work clothing, Thongsinthusak *et al*. (1991) suggests a 90% protection factor can be assumed for the portion of the body covered by work clothing (i.e., 10% of a pesticide passes through clothing). This is based on several studies that monitored residues both outside and inside clothing. Assuming a 90% protection factor for areas covered by a long-sleeved shirt, long pants, and shoes, the last row in Table 3 provides adjusted exposure monitoring results to be used for occupational exposure scenarios.

Table 4 summarizes exposure estimates for residential (assuming no clothing protection, as residents may wear only shorts and little else) and occupational (assuming workers wear shoes, long-sleeved shirt, and long pants) reentry onto non-irrigated turf. Exposure estimates for three application rates are included: 3.0 lbs AI/acre, the rate used in the study; 1.0 lb AI/acre, which is provided as a quick reference that essentially normalizes exposures by application rate; and 8.28 lbs AI/acre, the highest application rate for a carbaryl product on turf (0.19 lbs AI/1,000 ft^2 x 43,560 ft^2/acre = 8.28 lbs AI/acre). Exposures at rates other than the 3.0 lbs AI/acre used in the study were calculated by multiplying by ratios of the application rates (i.e., 1.0/3.0 and 8.27/3.0).

Mean and 95^{th} percentile exposures, normalized by hour and by body weight, are given in Table 4. To normalize exposures by hour, mean and 95^{th} percentile exposures from the 16-minute monitoring interval were divided by 16 minutes (to get µg/minute) and multiplied by 60 minutes per hour. To normalize exposures by body weight, individual total exposures were divided by individual body weights; means and 95^{th} percentiles were then calculated for the normalized exposures.

The 95^{th} percentile exposures were calculated in Excel, assuming a lognormal distribution (Frank, 2009). First the natural logarithm (ln) was calculated for each value using the LN function; the arithmetic mean and standard deviation were then calculated for the natural logarithms (am(lns) and asd(lns), respectively). The normal standard inverse cumulative distribution (NORMSINV) function, with a probability of 0.95, was used to get the inverse of the standard normal distribution curve (which is a normal distribution that has a mean of 0 and a standard deviation of 1). The NORMSINV result was multiplied by asd(lns); this product was added to am(lns), and the sum taken as the power of e with the exponent (EXP) function. Short-term exposures for residential scenarios (reported as µg/person and µg/person/hour) were based on the highest measured residues, which exceeded the 95th percentile. However, for short-term residential exposures normalized by body weight, and all occupational exposures, the 95th percentile exceeded all individual values. The spreadsheet used to calculate means and 95th percentiles of residential reentry exposures is copied in an Appendix at the end of this memo.

Table 4. Reentry Dermal Exposure Estimates for Non-Irrigated Turfgrass [a]

Application Rate [b] (lbs AI/acre)	Exposure (µg/person) [c]		Exposure Rate (µg/person/hour) [d]		Exposure (µg/kg) [e]		Exposure Rate (µg/kg/hour) [f]	
	Short-Term [g]	Long-Term [h]	Short-Term [g]	Long-Term [h]	Short-Term [g]	Long-Term [h]	Short-Term [g]	Long-Term [h]
Residential Scenarios [i]								
1.0	3,830	3,040	14,400	11,400	59.3	44.7	222	168
3.0 [j]	11,500 [k]	9,110	43,100 [k]	34,100	178	134	666	503
8.28 [l]	31,700	25,100	119,000	94,200	491	370	1,840	1,390
Occupational Scenarios [m]								
1.0	1,040	759	3,900	2,840	15.7	11.0	59.0	41.4
3.0 [j]	3,220	2,280	12,100	8,540	47.0	33.3	177	125
8.28 [l]	8,890	6,280	33,400	23,600	130	91.9	489	345

[a] Dermal exposure monitoring on a plot treated with Ronstar® 50WP (Rosenheck and Sanchez, 1995); reentry occurred on the application day, after spray had dried. Dermal exposures sum oxadiazon residues recovered from cotton gloves, hand wash, face/neck wipes, socks, and outer whole-body dosimeter; see Table 3 for individual results. All estimates were rounded to three significant figures.

[b] Application rate in pounds active ingredient (AI) per acre. Exposure estimates assume that exposure is directly proportional to application rate, and independent of the specific AI identity.

[c] Estimated exposure for individuals during a 16-minute reentry.

[d] Calculated from results in previous column as follows: (µg/person/16 minutes) x (60 minutes/hour).

[e] Estimated exposure for individuals during a 16-minute reentry. Calculated by dividing individual exposures (µg/person) by individual body weights from Table 3.

[f] Calculated by dividing individual hourly exposures (µg/person/hour) by individual body weights from Table 3.

[g] Short-term estimates are based on either the 95th percentile, or the highest measured residue if it exceeds the 95th percentile.

[h] Long-term estimates are based on the arithmetic mean of data from Rosenheck and Sanchez (1995).

[i] Residential reentry scenarios do not include adjustments for clothing protection, as residents may wear only shorts and little else.

[j] Application rate used by Rosenheck and Sanchez (1995).

[k] Highest measured residue exceeded 95th percentile values of 10,900 µg/person and 41,000 µg/person/hour, and short-term exposures in these columns are based on the highest measured residues.

[l] Maximum application rate to turf allowed on carbaryl product label; estimates adjusted for this rate were used in the carbaryl exposure assessment.

[m] Occupational reentry exposure estimates assume 90% clothing protection factor for individuals wearing shoes, shirt, and long pants.

Irrigated Oxadiazon Plot

Table 5 summarizes exposures for reentry onto Plot 2, the treated plot that was irrigated post-application with 1 inch of water. The same ten participants were monitored on this plot as on the non-irrigated plot; they showered and put on clean clothing between monitoring intervals. On this plot, the monitoring interval was 17 minutes. Oxadiazon was detected in all exposure monitoring matrices. Again, socks had higher residues than other matrices; on average, 37% of total dermal oxadiazon measured (mean: 3,040 µg/person) was recovered from socks (mean: 1,120 µg/person). As was true on the non-irrigated plot, more than a third of total dermal residues were recovered from socks. The exposure matrix coefficients of variation ranged from 22.0% for socks to 77.3% for hand washes; as with exposures measured on the non-irrigated plot, the variation among exposures of the ten volunteers on the irrigated plot is relatively small for an exposure monitoring study.

Table 5. Oxadiazon Residues on Dermal Exposure Monitoring Matrices for Reentry on Irrigated Turfgrass [a]

# [b]	Body Weight (kg)	Gloves (µg)	Hand Wash (µg)	Face/ Neck (µg)	Socks [c] (µg)	Arms [c] (µg)	Upper Body [c] (µg)	Lower Body [c] (µg)	Total Dermal [d] (µg/person)
1	63.6	361	24.0	1.51	1,090	239	736	682	3,130
2	58.6	315	8.67	1.76	1,410	176	385	938	3,230
3	72.7	219	4.23	1.58	767	227	490	674	2,380
4	59.5	447	21.6	2.61	1,050	205	502	918	3,150
5	84.1	782	53.6	3.80	1,330	398	959	807	4,330
6	54.5	376	8.13	1.81	1,050	49.2	437	626	2,550
7	90.0	420	21.8	1.01	865	82.6	576	541	2,510
8	57.1	282	3.25	0.904	857	108	273	377	1,900
9	86.4	726	32.9	1.61	1,400	368	540	653	3,720
10	65.9	845	20.1	1.79	1,390	324	373	499	3,450
Mean	69.4	477	19.8	1.84	1,120	218	527	672	3,040
SD	13.0	223	15.3	0.833	247	119	198	178	715
CV	18.8	46.8	77.3	45.3	22.0	54.7	37.5	26.6	23.6
Mean residue if wearing single layer of clothing [e]					112	21.8	52.7	67.2	753

[a] Data from Rosenheck and Sanchez (1995). Results corrected for field spike recoveries according to California Department of Pesticide Regulation practice (see Table 1), and rounded to three significant figures.

[b] Replicate number. Ten individuals were monitored during a 17-minute interval involving choreographed activities on turf sprayed with a solution of Ronstar® 50WP. Turf was irrigated with 0.1 inches water post-application. SD: standard deviation. CV: coefficient of variation.

[c] Replicates wore socks without shoes, and outer whole-body dosimeters that were then sectioned into three parts: arms, upper body, and lower body.

[d] Total residues recovered from cotton gloves, hand wash, face/neck wipes, socks, and outer whole-body dosimeter.

[e] Estimates assume 90% clothing protection factor for individuals wearing shoes, long-sleeved shirt, and long pants (Thongsinthusak *et al*., 1991). Used in calculating estimates of occupational exposure.

Comparison of results in Table 5 with those in Table 3 shows that dermal exposures were consistently lower on the irrigated plot than the non-irrigated plot. Mean total dermal residues for reentry on the non-irrigated plot were 9,110 ± 1,090 µg (Table 3), and mean total residues for the irrigated plot were 3-fold lower, at 3,040 ± 715 µg (Table 5).

Table 6 summarizes exposure estimates for reentry onto irrigated turf. These estimates are useful for estimating reentry exposure to pesticides when all product labels with turf use directions require "watering in," or irrigation following application.

Table 6. Reentry Dermal Exposure Estimates for Irrigated Turfgrass [a]

Application Rate [b] (lbs AI/acre)	Exposure (µg/person) [c]		Exposure Rate (µg/person/hour) [d]		Exposure (µg/kg) [e]		Exposure Rate (µg/kg/hour) [f]	
	Short-Term [g]	Long-Term [h]	Short-Term [g]	Long-Term [h]	Short-Term [g]	Long-Term [h]	Short-Term [g]	Long-Term [h]
Residential Scenarios [i]								
1.0	1,440	1,010	5,090	3,570	21.6	14.8	76.3	52.2
3.0 [j]	4,410	3,040	15,600	10,700	64.9	44.4	229	157
8.28 [k]	12,200	8,380	43,100	29,600	179	122	632	432
Occupational Scenarios [l]								
1.0	397	251	1,400	886	5.90	3.63	20.8	12.8
3.0 [j]	1,280	753	4,510	2,660	17.7	10.9	62.3	38.4
8.28 [k]	3,530	2,080	12,400	7,340	48.9	30.0	172	106

[a] Dermal exposure monitoring on a plot treated with Ronstar® 50WP (Rosenheck and Sanchez, 1995); reentry occurred on the application day. Turf was irrigated with 0.1 inches water post-application. Dermal exposures sum oxadiazon residues recovered from cotton gloves, hand wash, face/neck wipes, socks, and outer whole-body dosimeter; see Table 5 for individual results. All estimates were rounded to three significant figures.
[b] Application rate in pounds active ingredient (AI) per acre. Exposure estimates assume that exposure is directly proportional to application rate, and independent of the specific AI identity.
[c] Estimated exposure for individuals during a 17-minute reentry.
[d] Calculated from results in previous column as follows: (µg/person/17 minutes) x (60 minutes/hour).
[e] Estimated exposure for individuals during a 17-minute reentry. Calculated by dividing individual exposures (µg/person) by individual body weights from Table 5.
[f] Calculated by dividing individual hourly exposures (µg/person/hour) by individual body weights from Table 5.
[g] Short-term estimates are based on the 95th percentile of data from Rosenheck and Sanchez (1995).
[h] Long-term estimates are based on the arithmetic mean of data from Rosenheck and Sanchez (1995).
[i] Residential reentry scenarios do not include adjustments for clothing protection, as residents may wear only shorts and little else.
[j] Application rate used by Rosenheck and Sanchez (1995).
[k] Maximum application rate to turf allowed on carbaryl product label; estimates adjusted for this rate are included to allow comparison with the highest values in Table 4.
[l] Occupational reentry exposure estimates assume 90% clothing protection factor for individuals wearing shoes, shirt, and long pants.

Exposure Appraisal

Exposure monitoring by Rosenheck and Sanchez (1995) provided the best available data for estimating reentry turf exposure. This was a well-conducted study with apparently acceptable replication (10 subjects were monitored) and quality assurance. Monitoring intervals were short, just 16 or 17 minutes. Short monitoring intervals have been found to yield higher exposures than longer intervals; in a study of peach harvesters exposed to azinphos-methyl, hourly dermal exposure estimates were higher after 2-hour monitoring intervals than after 3- to 7-hour intervals, suggesting that extrapolation of short monitoring intervals to longer exposure intervals can result in overestimating exposure (Spencer *et al.*, 1995).

In this study, socks were the exposure matrix with the highest residues following reentry on both non-irrigated and irrigated turf, representing an average, 42% and 37% of total dermal exposures, respectively. Hand washes all contained quantifiable oxadiazon, which presumably either passed through the cotton gloves or came in at the wrist openings. But even after adding residues from gloves and hand washes to get total hand exposure, foot exposure as measured by socks was higher than hand exposure. Foot exposure measured by socks was also highest in another study, conducted by the Outdoor Residential Exposure Task Force, in which volunteers on turf treated with dithiopyr liquid were monitored after a Jazzercise® routine (Baugher *et al*., 2004). In that study, volunteers were also monitored after a different set activities intended to mimic children's play, and which required participants to be barefoot on turf at some points. Dithiopyr residues recovered from foot washes were lower than those in outer whole-body dosimeter lower leg and upper leg sections; however, the relative sampling efficiencies of sock dosimeters and foot washes are unknown. Volunteers in both studies wore socks without shoes during their Jazzercise® routines (Rosenheck and Sanchez, 1995; Baugher *et al*., 2004).

Exposure monitoring used outer whole-body dosimeters and socks without shoes, to mimic individuals wearing little clothing and going barefoot. This approach is appropriate for residential exposures, as individuals can be outdoors wearing shorts or swimming suits, and little else. Furthermore, residential exposure estimates for children will also be based on these data, and health-protective estimates assume they wear little clothing.

For occupational exposure estimates, reentry workers harvesting sod, working on golf courses, and performing other activities, are assumed to wear shoes, long-sleeved shirts, and long pants. These clothing items provide some degree of protection from pesticide residues, although as with gloves, the protection is not complete and some residues penetrate through the clothing or enter at openings. In a series of 26 studies, the Agricultural Reentry Task Force used both outer and inner whole-body dosimeters to monitor exposure. Bruce *et al.* (2006) calculated 75th percentile clothing penetration factors from these data, estimating the amounts reaching inner dosimeters at forearms, upper body, and lower body to be 26.2%, 16.5%, and 9.7%, respectively, of the total residues. If protection factors are estimated as the percent of residues retained by the outer dosimeter (i.e., 100% - percent penetration), the 75th percentile protection factors suggested by Bruce *et al*. (2006) would range from 73.8% for forearms to 90.3% for lower body. In this memo, a 90% protection factor was assumed for areas of the body covered by clothing. DPR is in the process of reviewing available data to determine if this protection factor is the best one supported by field studies.

Comparison with Sod Harvester Exposure Monitoring Study

Rosenheck and Sanchez (1995) is useful as a surrogate exposure monitoring study for turf reentry following pesticide applications. Another potential surrogate study available for turf reentry scenarios was conducted by the Agricultural Reentry Task Force (Merricks, 2000). This study monitored exposure of workers harvesting sod treated with 11.3 pounds chlorothalonil per acre. Exposure monitoring was conducted of six volunteers harvesting sod at 2 – 4 days post-application, with 3-hour monitoring intervals and using both inner and outer whole-body dosimeters, hand washes, and face/neck wipes.

The mean total of residues from outer whole-body dosimeters, hand washes, and face/neck wipes reported by Merricks (2000) was 65,571 µg/person; dividing that value by the 3-hour monitoring interval gives 23,190 µg/hour. Adjusting for the differences in application rate, the estimated sod harvester exposure for reentry following an application of 3 lbs AI/acre (the rate used by Rosenheck and Sanchez) would be 6,157 µg/hour. That is, a residential exposure estimate (without long-sleeved shirt and long pants) based on Day 2 data from Merricks (2000), would be 18% of the mean (long-term) estimate for residential exposure of 34,100 µg/hour based on Rosenheck and Sanchez (1995), as shown in Table 4.

Summing residues recovered by Merricks (2000) from inner whole-body dosimeters, along with face/neck wipes and hand washes, results in 24,732 µg/person; dividing that value by the 3-hour monitoring interval gives 8,244 µg/hour. Adjusting to an application rate of 3 lbs AI/acre gives an estimate of 2,189 µg/hour, which is 26% of the mean estimate for occupational exposure of 8,540 µg/hour based on Rosenheck and Sanchez (1995). This suggests that Merricks (2000) might underestimate some turf reentry exposures. The lower exposures estimated from the sod harvester study of Merricks (2000) might suggest that sod harvester activities result in less transfer of residues than the Jazzercise® routine used by Rosenheck and Sanchez (1995). Additionally, Merricks (2000) did not monitor foot exposure, which represented a substantial portion of total dermal exposure measured by Rosenheck and Sanchez (1995).

Because Merricks (2000) did not conduct monitoring until 2 – 4 days post-application, residues available for exposure had days in which to dissipate. Although initial deposition of residues during pesticide application is assumed to be determined by factors such as application method, product formulation and application rate, it is assumed to be independent of the specific AI. This assumption allows use of surrogate exposure monitoring data from the application day, as provided by Rosenheck and Sanchez (1995). Unlike initial deposition, however, residue dissipation is anticipated to be AI-specific. Data from Merricks (2000) is less useful as a surrogate study to estimate reentry exposure, because exposure monitoring did not occur on the application day and variable dissipation rates between AIs add uncertainty to exposure estimates on subsequent days.

Airborne Residue Results

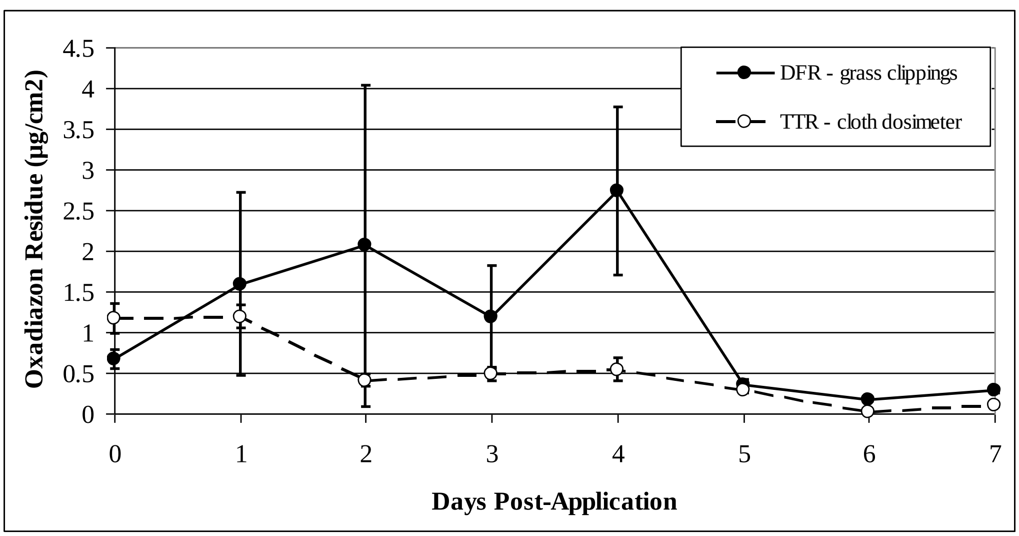
A total of eight samples were collected by Rosenheck and Sanchez (1995), four on each treated plot. Oxadiazon above the LOQ of 0.100 µg was recovered from only one pair of duplicate samples, collected 6 inches above the non-irrigated plot. The amounts collected from these samples were 0.102 µg and 0.144 µg, for a mean of 0.123 µg oxadiazon.

Oxadiazon Residue Dissipation on Turf

Non-Irrigated Turf

Figure 1 summarizes changes in oxadiazon over time, as measured by DFR and TTR. Results did not require correction for field spike recoveries. As summarized in Table 2, only DFR solution spikes on Day 0 at low and mid spike levels (0.5 µg and 5.0 µg spikes) had recoveries below 90%, and no DFR samples were in the ranges of those spikes.

Figure 1. Oxadiazon Residues Dislodged or Transferred from Non-Irrigated Turf [a]

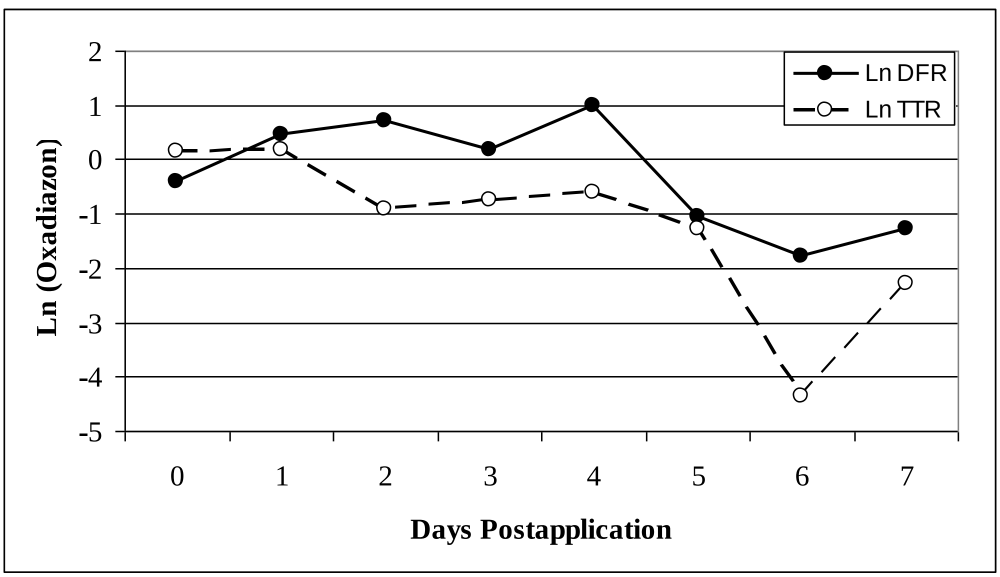


[a] Data from Rosenheck and Sanchez (1995), non-irrigated plot only. Dislodgeable foliar residues (DFR) involved dislodging residues from grass clippings. Transferable turf residues (TTR) used a roller over the top of a cloth placed on the turf to transfer residues from the turf to the cloth. Each point represents the mean of triplicate samples, and error bars are standard deviations. NOTE: Rainfall of 1 inch was reported on Day 5, and lesser amounts of rain were reported on days 6 and 7.

DFR measured by Rosenheck and Sanchez (1995) did not show a monotonic decrease over time; although residues on days 5 though 7 were lower than the DFR initially measured on Day 0, residues on days 1, 2, 4, and 7 exceeded those measured on the previous day. Rainfall of 1 inch was reported on Day 5, and lesser amounts of rain were reported on days 6 and 7. Rosenheck and Sanchez (1995) recognized that the rainfall could be responsible for some of the decrease in residues measured between days 4 and 5.

Log-transforming DFR data offers a slight improvement in the dissipation curve, as shown in Figure 2. Even so, given the rise and fall of mean residues from one day to the next, regressions conducted on original or log-transformed data do not support linear relationships between residues and post-application days (see the solid lines in both figures). Linear regressions conducted in Excel yielded adjusted R^2 values of 0.039 for non-transformed and 0.29 for log-transformed DFR data. If days with rainfall (Days 5 – 7) are excluded from the regression, the regression line for non-transformed data has an adjusted R^2 of 0.40, and the slope is actually positive (0.372), indicating an overall increase in measured residues over those days.

Figure 2. Log-Transformed Oxadiazon Residues Dislodged or Transferred from Non-Irrigated Turf [a]



[a] Data from Rosenheck and Sanchez (1995), non-irrigated plot only. Dislodgeable foliar residues (DFR) involved dislodging residues from grass clippings. Transferable turf residues (TTR) used a roller over the top of a cloth placed on the turf to transfer residues from the turf to the cloth. Each point represents the natural logarithm (ln) of the mean of triplicate samples. NOTE: Rainfall of 1 inch was reported on Day 5, and lesser amounts of rain were reported on days 6 and 7.

On every day except Day 0, TTR measured lower oxadiazon residues than did DFR. Additionally, as can be seen in Figure 1, mean TTR did not show large increases the way mean DFR did. However, like DFR, TTR increased from Day 0 to Day 1; it also increased from Day 2 through Day 4, and again between Day 6 and Day 7. Linear regression yields the following equation: TTR = 1.09 - 0.163 x days, with R^2 = 0.78. This corresponds to a half-life of 4 days [(ln 0.5)/(-0.163) = 4.25]. If days with rainfall (Days 5 – 7) are excluded from the regression, the regression line has an adjusted R^2 of 0.52, and the slope is -0.197, which again corresponds to a half-life of 4 days [(ln 0.5)/(-0.197) = 3.51]. Linear regression of log-transformed TTR data gives an R^2 of 0.58, meaning that non-transformed TTR data better fit a linear model than do log-transformed data.

Table 7 summarizes DFR and TTR data shown in Figure 1. Quantifiable oxadiazon resulted under both methods on every post-application day measured; measurements were taken through Day 7 (LOQ was 0.100 µg oxadiazon/300 ml hand wash and DFR dislodging solutions and 5.00 µg/sample for TTR cloth dosimeters). No quantifiable oxadiazon was measured in the triplicate pre-application samples for either method (results of pre-application sampling were omitted from Table 7 and Figures 1 and 2).

Table 7. Oxadiazon Turf Residues on Non-Irrigated Turf Measured by DFR and TTR [a]

Day [b]	DFR – Grass Clippings ($\mu g/cm^2$)					TTR – Cloth Dosimeter ($\mu g/cm^2$)				
	Replicate			Mean	SD [c]	Replicate			Mean	SD [c]
	A	B	C			A	B	C		
0	0.773	0.697	0.545	0.671	0.116	1.29	1.26	0.951	1.17	0.187
1	1.08	0.821	2.88	1.59	1.12	1.06	1.18	1.33	1.19	0.137
2	0.949	0.877	4.35	2.06	1.98	0.322	0.451	0.438	0.404	0.0710
3	1.87	0.637	1.06	1.19	0.625	0.390	0.546	0.492	0.476	0.0789
4	3.37	1.55	3.30	2.74	1.03	0.694	0.437	0.489	0.540	0.136
5 [d]	0.305	0.397	0.346	0.349	0.0462	0.290	0.254	0.285	0.276	0.0194
6 [d]	0.185	0.143	0.172	0.167	0.0218	0.0107	0.0162	0.0120	0.0130	0.00285
7 [d]	0.310	0.275	0.242	0.276	0.0337	0.0924	0.122	0.0924	0.102	0.0174

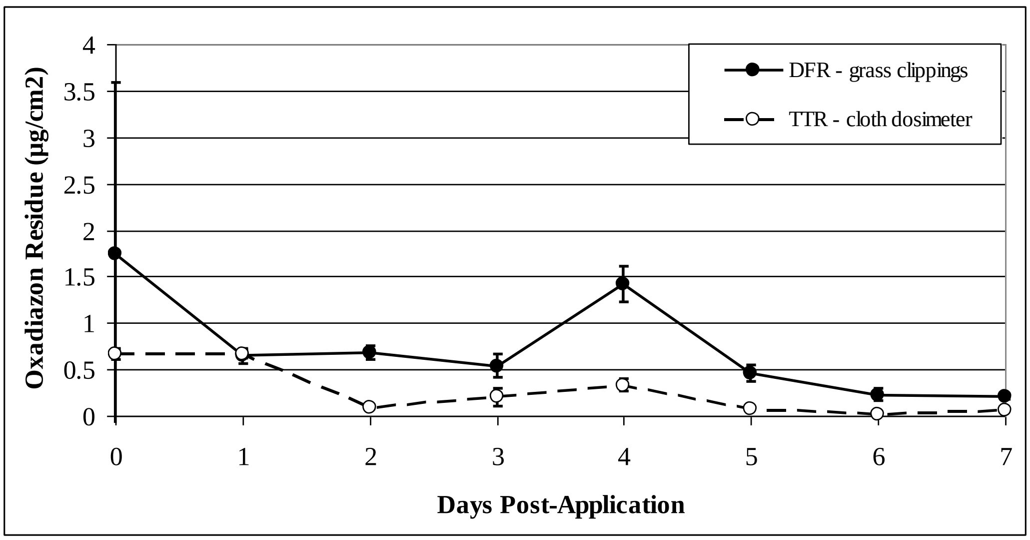
[a] Residues measured on a plot treated with Ronstar® 50WP (Rosenheck and Sanchez, 1995). Data are from non-irrigated plot only. DFR: dislodgeable foliar residues from grass clippings. TTR: transferable turf residue measured with cloth dosimeters. All estimates were rounded to three significant figures.
[b] Day post-application. Day 0 is the application day.
[c] SD: Standard deviation.
[d] Rain occurred on these days, potentially washing away some of the remaining oxadiazon residues.

Irrigated Turf

Figure 3 summarizes residue dissipation on the irrigated plot. With the exception of Day 1, residues measured using TTR were consistently lower than those measured using DFR. As on the non-irrigated plot, residues on the irrigated plot did not dissipate monotonically. Examination of Figure 3 and Figure 1 shows that the unexplained increase in oxadiazon measured by both DFR and TTR on Day 4 occurred on the irrigated plot as well as on the non-irrigated plot. Rosenheck and Sanchez (1995) noted the increase but could not explain it. As with the non-irrigated plot, a sharp decrease in residues between Day 4 and Day 5 was likely caused at least in part by rainfall of about an inch that fell before Day 5 samples were collected.

Linear regression yields the following equation: TTR = -0.568 - 0.0872 x days, with R^2 = 0.59. This corresponds to a half-life of 8 days [(ln 0.5)/(-0.0872) = 7.9]. Omitting days 5 – 7, when it rained, results in a regression with R^2 = 0.28, and a half-life of 6 days.

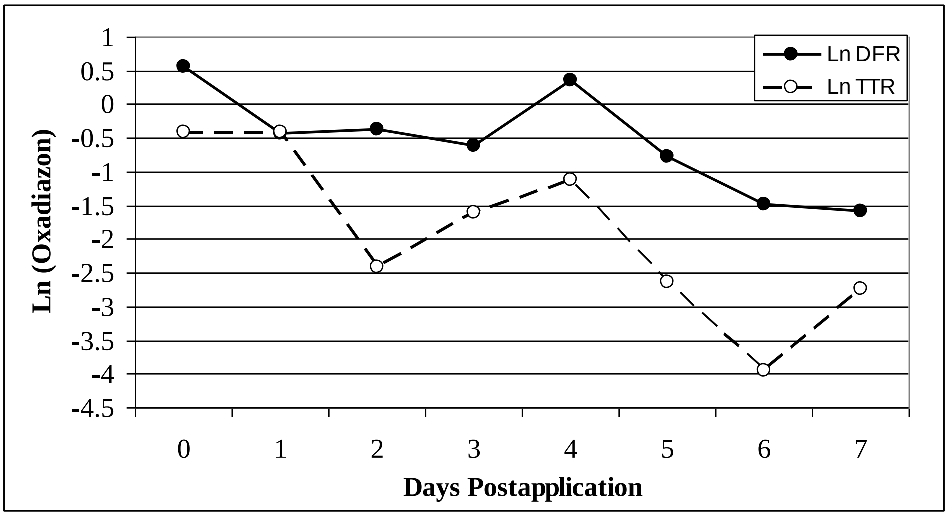
Figure 3. Oxadiazon Residues Dislodged or Transferred from Irrigated Turf [a]



[a] Data from Rosenheck and Sanchez (1995), residues from irrigated plot. Dislodgeable foliar residues (DFR) involved dislodging residues from grass clippings. Transferable turf residues (TTR) used a roller over a cloth to transfer residues from turf to the cloth. Each point represents the mean of triplicate samples, and error bars are standard deviations. NOTE: Rainfall of 1 inch was reported on Day 5, and lesser amounts of rain were reported on days 6 and 7.

Figure 4 shows log-transformed data. Linear regression of log-transformed data yields the following equation: ln TTR = -0.485 - 0.408 x days, with R^2 = 0.58. This corresponds to a half-life of 2 days [(ln 0.5)/(-0.408) = 1.7]. Omitting days 5 – 7 from the log-transformed data set yields an equation with a negative adjusted R^2, equal to -0.021, which is not useful for predicting residue dissipation.

Figure 4. Log-Transformed Oxadiazon Residues from Irrigated Turf [a]



[a] Data from Rosenheck and Sanchez (1995), residues from irrigated plot. Dislodgeable foliar residues (DFR) involved dislodging residues from grass clippings. Transferable turf residues (TTR) used a roller over a cloth to transfer residues from turf to the cloth. Each point represents the mean of triplicate samples. NOTE: Rainfall of 1 inch was reported on Day 5, and lesser amounts of rain were reported on days 6 and 7.

Table 8 summarizes turf residue data from the irrigated plot.

Table 8. Oxadiazon Turf Residues on Irrigated Turf Measured by DFR and TTR [a]

Day [b]	DFR – Grass Clippings ($\mu g/cm^2$)					TTR – Cloth Dosimeter ($\mu g/cm^2$)				
	Replicate			Mean	SD [c]	Replicate			Mean	SD [c]
	A	B	C			A	B	C		
0	0.704	0.645	3.86	1.74	1.84	0.683	0.590	0.711	0.662	0.0631
1	0.569	0.625	0.734	0.643	0.0835	0.629	0.645	0.711	0.662	0.0434
2	0.764	0.626	0.657	0.682	0.0726	0.0771	0.0776	0.115	0.0898	0.0216
3	0.424	0.514	0.666	0.535	0.122	0.315	0.152	0.141	0.202	0.0976
4	1.19	1.51	1.55	1.42	0.195	0.315	0.402	0.266	0.328	0.0687
5 [d]	0.558	0.387	0.422	0.456	0.0900	0.0694	0.0678	0.0749	0.0707	0.00372
6 [d]	0.168	0.209	0.294	0.224	0.0644	0.0230	0.0167	0.0176	0.0191	0.00341
7 [d]	0.213	0.227	0.175	0.205	0.0269	0.0716	0.0640	0.0585	0.0647	0.00659

[a] Residues measured on a plot treated with Ronstar® 50WP then irrigated with 0.1 inches water (Rosenheck and Sanchez, 1995). DFR: dislodgeable foliar residues from grass clippings. TTR: transferable turf residue measured with cloth dosimeters. All estimates were rounded to three significant figures.
[b] Day post-application. Day 0 is the application day.
[c] SD: Standard deviation.
[d] Rain occurred on these days, potentially washing away some of the remaining oxadiazon residues.

Appraisal of Oxadiazon Residue Dissipation Data

The decision to conduct this study during winter (January 1994) on dormant turf was not explained, and may simply have been due to convenience. Rosenheck and Sanchez (1995) did explain why the study was conducted in North Carolina (page 21): "Since Ronstar® 50WP is typically used in the east/southeast region of the United States, this study was conducted at a location representative of the major use area for this product, North Carolina." It's possible that the study was conducted in winter to minimize potential for rain during the study. A state climatology website maintained by North Carolina State University (http://www.nc-climate.ncsu.edu/climate/ncclimate.html#precip; accessed July 27, 2011) summarizes statewide rainfall trends as follows: "While there are no distinct wet and dry seasons in North Carolina, average rainfall does vary around the year. Summer precipitation is normally the greatest, and July is the wettest month." The study site is in Johnston County, in the central part of the state. Monthly rainfall for the county, averaged 1971 – 2000, is in the range of 3.5 – 4.5 inches during winter months, and 4.5 – 5.5 inches in summer, suggesting that it would be difficult to predict a rain-free week for the study to be conducted at any time of year.

Draft guidance from U.S. EPA (1998b) for the conduct of TTR studies state the following about study timing: "Sampling should be conducted during the intended use season or under climatic conditions that are essentially representative of those encountered during the activity being studied. Applications should be made after mowing and watering. Weather forecasts should be studied, as much as possible, to avoid initiating the testing immediately (e.g., within 24 hours) before a precipitation event." Although turf reentry occurs in winter, it is anticipated more often and for longer durations in summer. No studies are available that compare dormant to actively growing turf, and residue transfer and dissipation could be different in summer—or in California at any time of year because of differences in climate—than what Rosenheck and Sanchez (1995) found.

On both the irrigated and non-irrigated plots, most TTR samples measured somewhat lower oxadiazon residues than DFR samples. In a study comparing sensitivity of the California roller method to other turf residue methods, Klonne *et al*. (2001) found that the "foliar wash technique," which was similar to the DFR method used by Rosenheck and Sanchez (1995), "was much more sensitive to the hydrophilic residues of the 2,4-D liquid and granular formulations but was no more sensitive to the lipophilic dithiopyr than the other techniques on the day of application." The octanol-water partition coefficient (Log K_{ow}) for oxadiazon is 4.80 (NLM, 2011). For comparison, 2,4-D (acid form, used in the study) has a Log K_{ow} of 2.81 (NLM, 2011), and the Log K_{ow} for dithiopyr is 4.75 (Dow AgroSciences LLC, 2011). These data suggest that oxadiazon is slightly more lipophilic than dithiopyr.

Rosenheck and Sanchez (1995) monitored both exposure and turf residue transfer data. These data were intended to be used to calculate transfer coefficients (TCs), for use in estimating reentry exposure following different AIs. The use of transfer coefficients and DFR in estimating exposures of fieldworkers in treated crops is well accepted. Although multiple studies support a correspondence between DFR residues on crops and fieldworker exposures (e.g., Zweig *et al.*, 1985; Bruce *et al.*, 2006), available data do not appear to support a consistent relationship between TTR and exposure (Baugher *et al.*, 2004). This suggests that the model which works well for fieldworker exposures might not apply to post-application exposures on turf. For this reason, post-application exposures on turf are more appropriately based on exposure monitoring data.

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Appendix: Excel Spreadsheets Used to Calculate Residential Exposures in Tables 4 and 6

Spreadsheet for calculations in Table 4:

Replicate Number	Body wt (kg)	Rounded (µg/person)	Ln (µg/person)	Rounded (µg/hr)	Ln (µg/hr)	Rounded (µg/kg)	Ln (µg/kg)	Rounded (µg/kg/hr)	Ln (µg/kg/hr)
1	63.6	7,770	8.958025	29,100	10.27978	122	4.804021	458	6.126869
2	58.6	9,670	9.176784	36,300	10.49854	165	5.105945	619	6.428105
3	72.7	7,920	8.977146	29,700	10.2989	109	4.691348	409	6.013715
4	59.5	9,780	9.188095	36,700	10.50985	164	5.099866	615	6.421622
5	84.1	**11,500**	9.350102	**43,100**	10.67186	137	4.919981	514	6.242223
6	54.5	8,790	9.08137	33,000	10.40313	161	5.081404	604	6.403574
7	90	9,420	9.15059	35,300	10.47235	105	4.65396	394	5.976351
8	59.1	8,240	9.016756	30,900	10.33851	139	4.934474	521	6.25575
9	86.4	9,100	9.11603	34,100	10.43779	105	4.65396	394	5.976351
10	65.9	8,870	9.09043	33,300	10.41219	135	4.905275	506	6.226537
Mean	**69.4**	**9,106**	**9.111**	**34,150**	**10.432**	**134**	**4.885**	**503**	**6.207**
SD	**13.0**	**1,090**	**0.116**	**4,089**	**0.116**	**23.7**	**0.179**	**89.0**	**0.179**
CV	**18.8**	**12.0**	**1.27**	**11.97**	**1.11**	**17.7**	**3.66**	**17.7**	**2.88**
95th %ile			**10,948**		**41,054**		**178**		**666**
Rounded			**10,900**		**41,000**		**178**		**666**

Spreadsheet for calculations in Table 6:

Replicate Number	Body wt (kg)	Rounded (µg/person)	Ln (µg/person)	Rounded (µg/hr)	Ln (µg/hr)	Rounded (µg/kg)	Ln (µg/kg)	Rounded (µg/kg/hr)	Ln (µg/kg/hr)
1	63.6	3,130	8.048788	11,000	9.30992	49.2	3.895894	174	5.159055
2	58.6	3,230	8.080237	11,400	9.341369	55.1	4.00915	194	5.267858
3	72.7	2,380	7.774856	8,400	9.035987	32.7	3.487375	115	4.744932
4	59.5	3,150	8.055158	11,100	9.316289	52.9	3.968403	187	5.231109
5	84.1	4,330	8.373323	15,300	9.634454	51.5	3.941582	182	5.204007
6	54.5	2,550	7.843849	9,000	9.10498	46.8	3.845883	165	5.105945
7	90	2,510	7.828038	8,860	9.089169	27.9	3.328627	98.5	4.590057
8	59.1	1,900	7.549609	6,710	8.81074	32.2	3.471966	114	4.736198
9	86.4	3,720	8.221479	13,100	9.48261	43.1	3.763523	152	5.023881
10	65.9	3,450	8.14613	12,200	9.407261	52.4	3.958907	185	5.220356
Mean	**69.4**	**3,035**	**7.992**	**10,707**	**9.253**	**44.4**	**3.767**	**157**	**5.028**
SD	**13.0**	**715**	**0.242**	**2,525**	**0.242**	**9.9**	**0.246**	**35.1**	**0.247**
CV	**18.8**	**23.6**	**3.03**	**23.59**	**2.62**	**22.4**	**6.54**	**22.4**	**4.90**
95th %ile			**4,406**		**15,551**		**64.9**		**229**
Rounded			**4,410**		**15,600**		**64.9**		**229**